

CLAIMS

1. A semiconductor device manufacturing method comprising the steps of:

generating a film forming gas by using any one of a silicon-contained organic compound having a siloxane bond and a silicon-contained organic compound having a CH₃ group and in addition H₂O, setting a flow rate ratio of H₂O to the silicon-contained organic compound to 4 or more, and adjusting a gas pressure to 1.5 Torr or more;

applying a power to the film forming gas to generate a plasma thereof so as to react it, and thus forming a low-dielectric insulating film on a substrate;

generating a process gas containing at least any one of He, Ar, H₂ and deuterium;

generating a plasma by applying a power to the process gas; and

bringing the low-dielectric insulating film into contact with the plasma of the process gas.

2. A semiconductor device manufacturing method according to claim 1, wherein the power applied to the film forming gas is a power having a frequency of 1 MHz or more.

3. A semiconductor device manufacturing method according to claim 1, wherein the power applied to the process gas is a power having a frequency of below 1 MHz.

4. A semiconductor device manufacturing method according to any one of claims 1 and 2, wherein the power applied to the process gas is a power having a frequency of 1 MHz or more.

5. A semiconductor device manufacturing method according to any one of claims 1 to 4, wherein a pressure of the process gas is adjusted to 1.0 Torr or less.

6. A semiconductor device manufacturing method according to any one of claims 1 to 4, wherein a pressure of the process gas is adjusted to 0.5 Torr or less.

7. A semiconductor device manufacturing method according to any one of claims 1 to 6, wherein, in the step of bringing the low-dielectric insulating film into contact with the plasma

of the process gas, a temperature of the low-dielectric insulating film is raised up to 375 °C or more.

8. A semiconductor device manufacturing method according to any one of claims 1 to 7, wherein the step of bringing the low-dielectric insulating film into contact with the plasma of the process gas is followed by the further step of:

removing a surface layer of the low-dielectric insulating film.

9. A semiconductor device manufacturing method according to claim 8, wherein the step of removing the surface layer of the low-dielectric insulating film is followed by the further subsequent step of:

increasing a temperature of the low dielectric insulating film to 375 °C or more at an atmospheric pressure or a low pressure, and then bringing the low-dielectric insulating film into contact with a process gas having a CH₃ group, while the low-dielectric insulating film is not brought into contact with an atmosphere.

10. A semiconductor device manufacturing method comprising the steps of:

generating a film forming gas by using any one of a silicon-contained organic compound having a siloxane bond and a silicon-contained organic compound having a CH₃ group and in addition H₂O, setting a flow rate ratio of H₂O to the silicon-contained organic compound to 4 or more, and adjusting a gas pressure to 1.5 Torr or more;

applying a power to the film forming gas to generate a plasma thereof so as to react it, and thus forming a low-dielectric insulating film on a substrate; and

annealing the low-dielectric insulating film in an atmosphere of a nitrogen gas or an inert gas at a temperature of 400 °C or more.

11. A semiconductor device manufacturing method according to claim 10, wherein the power applied to the film forming gas is a power having a frequency of 1 MHz or more.

12. A semiconductor device manufacturing method

according to claim 10 or 11, wherein the step of annealing the low-dielectric insulating film is followed by the further step of:

removing a surface layer of the low-dielectric insulating film.

13. A semiconductor device manufacturing method according to claim 12, wherein the step of removing the surface layer of the low-dielectric insulating film is followed without bringing the low-dielectric insulating film into contact with an atmosphere by the further subsequent step of:

increasing a temperature of the low-dielectric insulating film to 375 °C or more at an atmospheric pressure or a low pressure, and then bringing the low-dielectric insulating film into contact with a process gas having a CH₃ group.

14. A semiconductor device manufacturing method according to any one of claims 9 and 13, wherein the process gas having the CH₃ group is a methylsilane consisting of any one of monomethylsilane (SiH₃(CH₃)), dimethylsilane (SiH₂(CH₃)₂), trimethylsilane (SiH(CH₃)₃), or tetramethylsilane (Si(CH₃)₄), or an alkoxy silane consisting of any one of trimethylmethoxysilane (Si(CH₃)₃(OCH₃)), dimethyldimethoxysilane (Si(CH₃)₂(OCH₃)₂), or methyltrimethoxysilane (TMS: Si(CH₃)(OCH₃)₃).

15. A semiconductor device manufacturing method according to any one of claims 1 to 14, wherein a pressure of the film forming gas is adjusted to 1.75 Torr or more.

16. A semiconductor device manufacturing method according to any one of claims 1 to 15, wherein in the step of forming the low-dielectric insulating film, a temperature of the substrate is raised up to 25 °C or more but 400 °C or less.

17. A semiconductor device manufacturing method comprising the steps of:

generating a film forming gas by using any one of a silicon-contained organic compound having a siloxane bond and a silicon-contained organic compound having a CH₃ group and in

addition H₂O, and setting a flow rate ratio of H₂O to the silicon-contained organic compound to 12 or more;

increasing a temperature of a substrate up to 200 °C or more but 400 °C or less; and

applying a power to the film forming gas to generate a plasma thereof so as to react it, and thus forming a barrier insulating film on the substrate whose temperature is raised.

18. A semiconductor device manufacturing method according to claim 17, wherein, in the step of generating the film forming gas, a pressure of the film forming gas is adjusted to below 1.0 Torr and, in the step of forming the barrier insulating film, a power of a frequency of below 1 MHz is applied to the substrate to bias the substrate and to generate a plasma of the film forming gas by the power of the frequency of below 1 MHz so as to react it, and thus the barrier insulating film is formed.

19. A semiconductor device manufacturing method according to claim 17, wherein, in the step of generating the film forming gas, a pressure of the film forming gas is adjusted to below 1.0 Torr and, in the step of forming the barrier insulating film, a power of a frequency of below 1 MHz is applied to the substrate to bias the substrate while at least the power of the frequency of 1 MHz or more out of the power of the frequency of below 1 MHz or the power of the frequency of 1 MHz or more is applied to the film forming gas, whose pressure is adjusted to 1.0 Torr or more, to generate a plasma thereof so as to react it, and thus the barrier insulating film is formed.

20. A semiconductor device manufacturing method comprising the steps of:

generating a film forming gas by using any one of a silicon-contained organic compound having a siloxane bond and a silicon-contained organic compound having a CH₃ group and H₂O, and setting a flow rate ratio of H₂O to the silicon-contained organic compound to 12 or more;

adjusting a pressure of the film forming gas to below 1.0 Torr;

increasing a temperature of a substrate up to 200 °C or more but 400 °C or less;

applying a power of a frequency of below 1 MHz to the substrate to bias the substrate and to generate a plasma of the film forming gas by the power of the frequency of below 1 MHz so as to react the plasma, and thus forming a first insulating film;

generating the film forming gas;

adjusting a pressure of the film forming gas to 1.0 Torr or more;

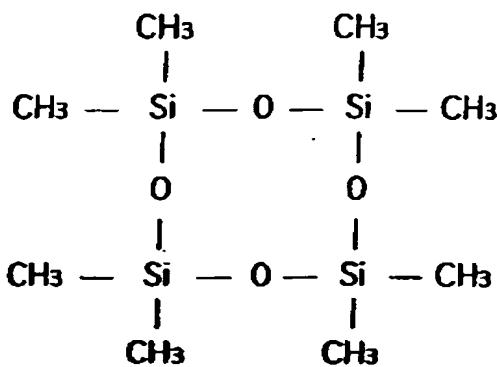
increasing a temperature of a substrate up to 200 °C or more but 400 °C or less; and

applying a power of a frequency of below 1 MHz to the substrate to bias the substrate while applying at least the power of the frequency of 1 MHz or more out of the power of the frequency of below 1 MHz or the power of the frequency of 1 MHz or more to the film forming gas, whose pressure is adjusted to 1.0 Torr or more, to generate a plasma thereof so as to react it, and thus forming a second insulating film on the first insulating film, whereby the barrier insulating film composed of the first insulating film and the second insulating film is formed.

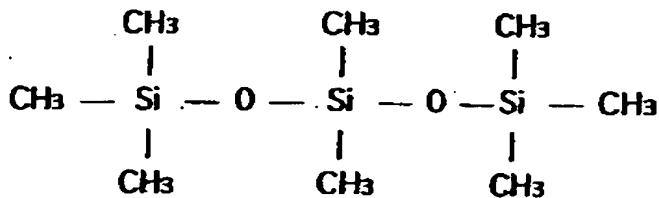
21. A semiconductor device manufacturing method according to any one of claims 17 to 20, wherein dinitrogen monoxide (N₂O) is added, or nitrogen (N₂) or ammonia (NH₃) is added, or dinitrogen monoxide (N₂O) and ammonia (NH₃) are added to the film forming gas.

22. A semiconductor device manufacturing method according to any one of claims 1 to 21, wherein the silicon-contained organic compound having the siloxane bond consists of any one of hexamethyldisiloxane (HMDSO: (CH₃)₃Si-O-Si(CH₃)₃),

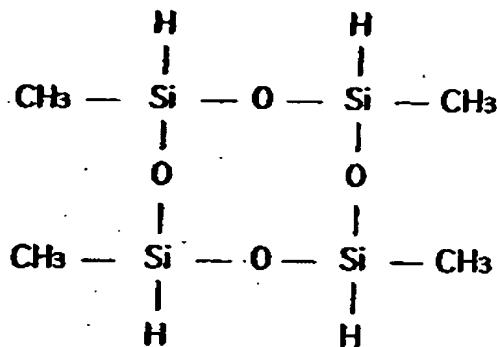
octamethylcyclotetrahexane (OMCTS)



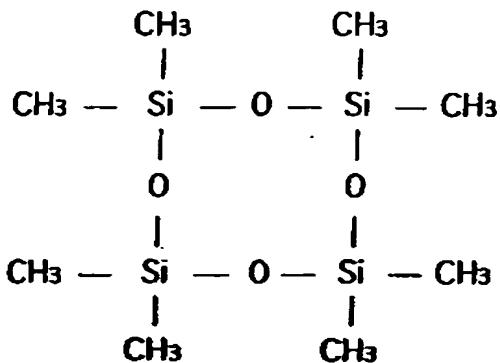
octamethyltrisiloxane (OMTS), or



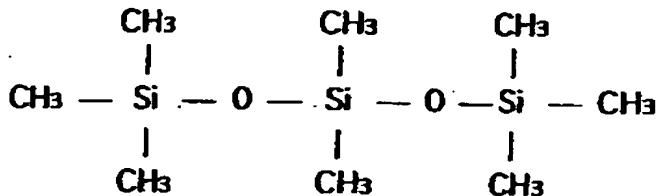
tetramethylcyclotetrasiloxane (TMCTS)



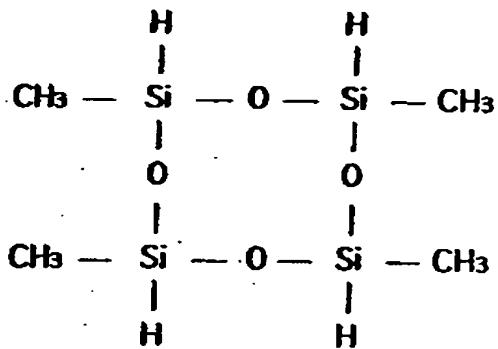
23. A semiconductor device manufacturing method according to any one of claims 1 to 21, wherein the silicon-contained organic compound having the siloxane bond consists of a compound obtained by replacing at least one CH_3 group of any one of hexamethyldisiloxane (HMDSO: $(\text{CH}_3)_3\text{Si}-\text{O}-\text{Si}(\text{CH}_3)_3$), octamethylcyclotetrahexane (OMCTS)



octamethyltrisiloxane (OMTS), or



tetramethylcyclotetrasiloxane (TMCTS)



with F.

24. A semiconductor device manufacturing method according to any one of claims 1 to 23, wherein the silicon-contained organic compound having the CH_3 group is a methylsilane consisting of any one of monomethylsilane ($\text{SiH}_3(\text{CH}_3)$), dimethylsilane ($\text{SiH}_2(\text{CH}_3)_2$), trimethylsilane ($\text{SiH}(\text{CH}_3)_3$), or tetramethylsilane ($\text{Si}(\text{CH}_3)_4$), or an alkoxy silane consisting of any one of trimethylmethoxysilane ($\text{Si}(\text{CH}_3)_3(\text{OCH}_3)$), dimethyldimethoxysilane ($\text{Si}(\text{CH}_3)_2(\text{OCH}_3)_2$), or methyltrimethoxysilane (TMS: $\text{Si}(\text{CH}_3)(\text{OCH}_3)_3$).

25. A semiconductor device manufacturing method according to any one of claims 1 to 24, wherein C_xH_y (x, y are a positive integer), $C_xH_yF_z$ or $C_xH_yB_z$ (x, y are 0 (where, except the case $x=y=0$) or a positive integer, z is a positive integer) is added to the film forming gas.

26. A semiconductor device manufacturing method according to claim 25, wherein C_xH_y is C_2H_4 .

27. A semiconductor device manufacturing method according to claim 25, wherein $C_xH_yF_z$ is C_3F_8 , C_4F_8 or CHF_3 .

28. A semiconductor device manufacturing method according to claim 25, wherein $C_xH_yB_z$ is B_2H_6 .

29. A semiconductor device manufacturing method comprising the steps of:

forming the low-dielectric insulating film by the semiconductor device manufacturing method set forth in Claim 1; and

forming the barrier insulating film by the semiconductor device manufacturing method set forth in Claim 17 or 20.

30. A semiconductor device manufacturing method comprising the steps of:

forming the low-dielectric insulating film by the semiconductor device manufacturing method set forth in Claim 10; and

forming the barrier insulating film by the semiconductor device manufacturing method set forth in Claim 17 or 20.

31. A semiconductor device manufacturing method according to claim 29 or 30, wherein the step of forming the low-dielectric insulating film is followed without exposing the low-dielectric insulating film to an atmosphere by the further subsequent step of:

forming the barrier insulating film without exposing the low-dielectric insulating film to an atmosphere.

32. A semiconductor device manufacturing method according to any one of claims 1 to 31, wherein wirings or electrodes consisting mainly of a copper film are formed on the substrate.

33. A semiconductor device manufactured by the semiconductor device manufacturing method set forth in any one of claims 1 to 32.